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METEOROLOGICAL OFFICE

PROFESSIONAL NOTES NO. 62

(Second Number of Volume V)

BAROMETER FLUCTUATIONS AT MALTA

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METEOROLO
30 JUN 1931
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BAROMETER FLUCTUATIONS AT MALTA

By R. C. SUTCLIFFE, Ph.D.

Irregular pressure variations of the type which give what Sir Napier Shaw has called embroidery of the barogram[1] and not readily explained as due to moving depressions or normal atmospheric discontinuities have been observed fairly frequently (several times each year) at Malta.

A particularly unusual barograph trace on June 27, 1929, when the pressure rose and fell nearly four millibars in about one and a half hours, was considered to be of sufficient interest to call for close investigation. The autographic records of the Malta Meteorological Office for the period[2] from 1600 on the 26th to 0800 on the 27th are shown in Fig. 1. The large pressure fluctuation about 0100 is clearly associated with the temporary displacement of a south-easterly by a westerly wind. The meteorological situation in the vicinity at the time is shown in the two synoptic charts of Fig. 2. A shallow depression over Italy had developed a secondary to the south of Tripoli which moved north-eastwards. The front which is shown connecting the two centres moved as a whole eastwards. The pressure irregularity would be expected to be in some way associated with the passage of the front, but it is fairly clear from the records of Fig. 1 that the true frontal passage did not come until about 0500 with the north-easterly wind ; after the squall at 0100 the wind returned to SE.

A feature of the synoptic charts of Fig. 2 which requires explanation is the motion of the section of the front A B. To agree with the gradient it must be marked as a warm front, but it has clearly moved eastwards, that is as a cold front. This phenomenon of a front moving against the gradient is not unknown, it is in fact fairly common in the shallow depressions of the Mediterranean and can probably be explained as follows.

The temperature gradient is clearly such that the upper wind in the Malta area will differ from the surface wind by the vector addition of a component from a south-westerly point. This is seen in the two pilot-balloon ascents of Table I. showing the upper winds at 1720 on June 26 and 0800 on June 27.

TABLE I.

	Surface.	1000 ft.	2000 ft.	3000 ft.	4000 ft.	5000 ft.	6000 ft.	7000 ft.
1720, June 26—								
Dirn. (° from N.)	130	136	147	142	159	197	184	180
Vel. (m.p.h.) ..	10	13	15	17	16	12	15	16
0800, June 27—								
Dirn. (° from N.)	60	59	259	257				
Vel. (m.p.h.) ..	16	15	3	18				

[1] Forecasting Weather, Constable & Co., 1923, Chap. XI, and Manual of Meteorology, Vol. II, Camb. Univ. Press, 1928, pp. 390–5.

[2] Central European Time (C.E.T.), one hour fast on Greenwich, is used throughout.

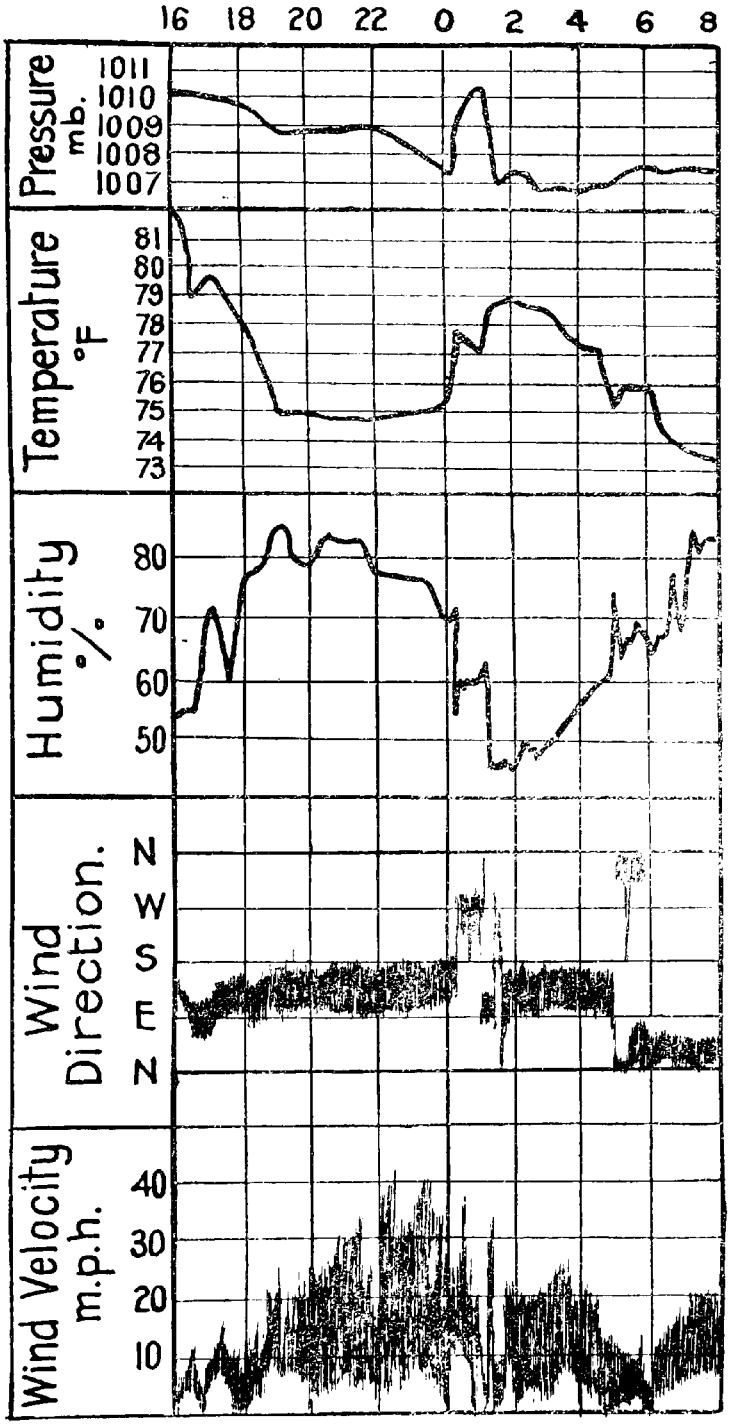

FIG. 1.—Autographic records at Malta June 26–27, 1929.

(5177) Wt. 29147/1631/2444 625 6/31 Hw. G. 1/27.

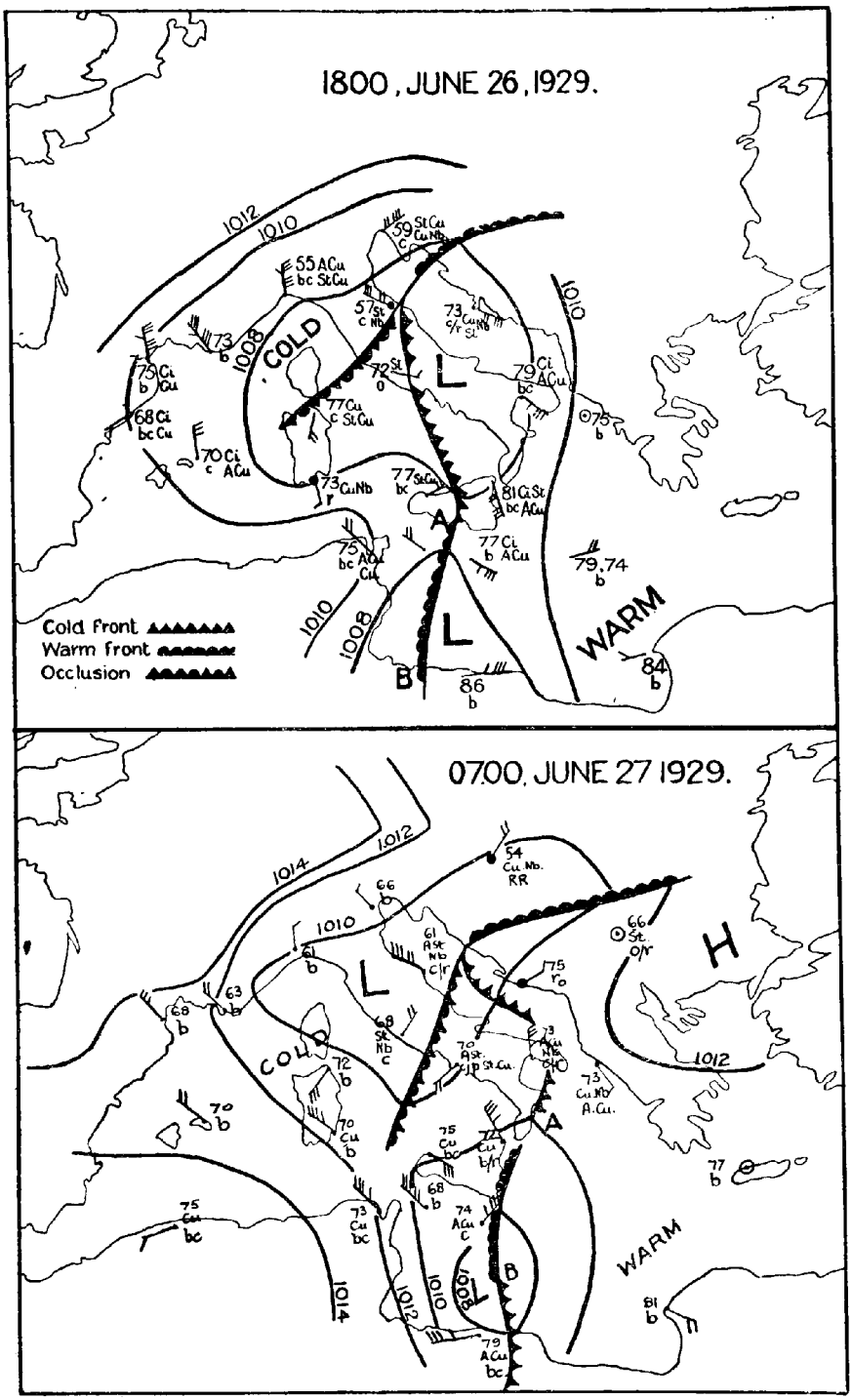

FIG. 2.—Synoptic charts for 1800, June 26 and 0700, June 27, G.M.T. (1900 and 0800 C.E.T.)

At the time of the first ascent Malta was in the warm air, at the time of the second in the colder mass. It needs to be observed that the change from a NE. to a SW. wind between 1,000 and 2,000 feet on the 27th is no certain evidence of the existence of a discontinuity of air mass at this level. Although at first sight there appears to be a discontinuous change it is easily seen by taking vector differences that the change is approximately continuous. The effect of the temperature gradient will therefore be to reverse the feeble surface pressure gradient at no very great altitude, and the front will move eastwards by the colder air overrunning the warmer. A vertical section of the air masses normal to the surface warm front may be represented by Fig. 3.

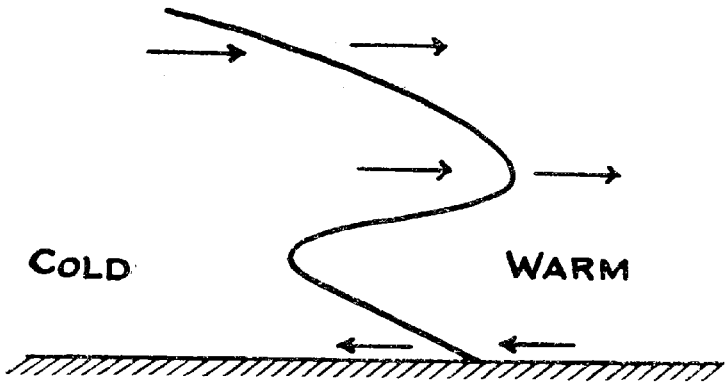

FIG. 3.

The diagram is drawn as though the situation were stable, which it clearly is not. The shearing between the upper colder and the lower warmer air will continue until, in some way by instability or turbulence, the warm tongue is broken off. The argument is valid if the frontal surface has no real existence as a true surface of discontinuity, and in practice one does not get a marked discontinuity but merely a rapid continuous change. Also there is no reason why, if the temperature contrast is not well marked, the " warm " tongue with the overrunning " cold " tongue need be spontaneously unstable, although as the tongue becomes more extended and the temperature contrast increases instability will ultimately ensue. The mechanism, then, of this movement of a cold front against the gradient is by a process of overrunning cold air and mixing of the surface warm with the upper cold air by instability.

It will now be seen how these considerations can be used to interpret the instrumental records of Fig. 1. The fall in temperature after 1600 to 75° F. at 1900 was the normal nocturnal cooling due to the cold sea with a surface temperature from 70° to 75° F. and radiation from the island ; the gradual fall of pressure was due to the deepening or approach of the shallow depression to the south. The only idea which presents itself to account for the

sudden rise in pressure followed by an almost as sudden fall is that it was a static effect produced by the substitution of a warm by a cold air mass. There is no way of proving that this pressure variation was not transmitted to the surface from the upper air but its discontinuous nature suggests a cause originating near the surface, and an explanation of this follows directly from the considerations above. Variations in pressure would have been caused by variations in the thickness of the surface layer of the warm south-easterly wind, the maximum effect being produced by a break through of the colder upper current to the surface.

It is not necessary to assume that the cold air reached the surface, but it becomes simpler if we think of the upper westerly current actually doing so during the squall. The rise in temperature was natural as a result of the destruction of the surface temperature inversion by the squall or as caused by subsidence if the air had come to the surface from above. The low relative humidity would be expected in either case. The return to a SE. surface wind with the fall of pressure was the return to a thicker layer of warm surface air. Temperature began to fall off again by surface cooling as soon as the disturbance had passed. It was with the arrival of the north-easterly wind at 0500 that the surface front finally passed and thereafter temperature fell off rapidly. Considered as a purely static effect it is easily shown that the substitution of a warm current by a colder one through a layer of 6,000 feet with a mean temperature difference of 10° F. between the air masses would give a pressure rise of about 4 mb. Unfortunately no observations of upper air temperature are available, but there is nothing improbable in these figures. The weather at Malta was throughout undisturbed. June is normally a very dry month and in 1929 was entirely rainless, but on the 26th there was considerable high cloud, and one bank at 1900 had very thick *Fallstreifen*. This is entirely in agreement with the idea of overrunning cold air.

After the above account was written there occurred several periods of large pressure fluctuations which included some of the largest on record. On one occasion near the time of observation at 1400 on June 6, 1930, pressure fell 2 mb. in 10 minutes and the observer noted that the falling motion was sufficiently rapid to be clearly perceptible to the eye. During the night July 12–13, 1930, pressure was again very disturbed and rose at one time almost 6 mb. in 10 or 15 minutes. This occasion is perhaps of sufficient interest to justify a more detailed account. The autographic records set out in Fig. 4 show the unsteady barograph trace from 1200 on the 12th to 0600 on the 13th with sympathetic variations in the other records, particularly the anemogram, the peaks of high pressure plainly coming with the W. or NW. wind and the low pressure with the S. and later SE.–NE. wind. While the connexion between high pressure and low temperature also appears definite enough, too much stress should not be placed on this

since during the early part of the period there was an alternation between land and sea breezes, and later the rainfall prevents any simple interpretation of the thermogram.

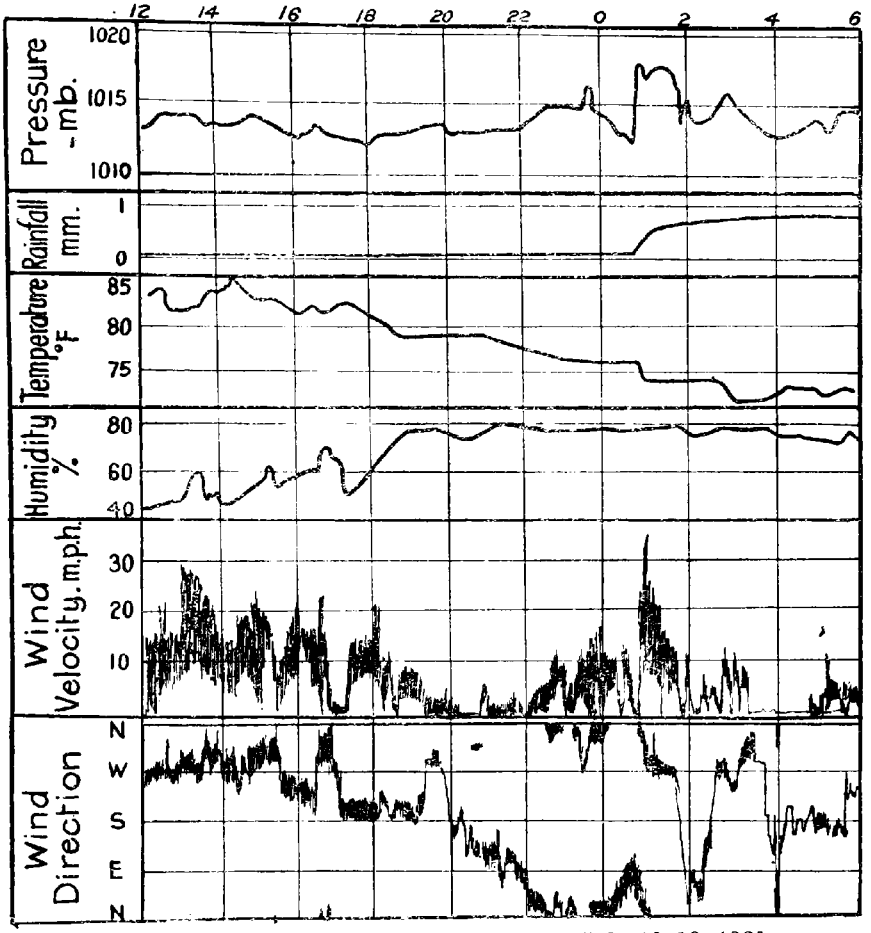

FIG. 4.—Autographic records at Malta on July 12–13, 1930.

The situation over the central Mediterranean was dominated by a rather deep but weakening depression over Italy. The first cold front had passed Malta on the 11th so that the central Mediterranean was flooded with air of cold origin. No further fronts were defined although there was clearly much cooler air moving across the western Mediterranean and consequently a large temperature gradient. The explanation appears to be on the following lines. Solar heating over North Africa had been sufficient to destroy the pressure gradient near the surface—a process mentioned by C. K. M. Douglas in describing thunderstorm types over France.[3] The surface air over this part of the Mediterranean became, therefore, warm, stagnant and gradually more humid whilst the wind remained westerly above. The horizontal temperature gradient and the surface heating together imply an increasing vertical lapse-rate so that the air must tend

[3] *London Meteorological Office, Prof. Notes* No. 8, 1920.

to become gradually less stable. The breakdown in stability apparently takes the form of this irregular large-scale convection in which the colder air breaks through to the surface. On this particular occasion conditions were thundery with thick banks of high and medium cloud ; a thunderstorm occurred near the station at 1630 and lightning was observed most of the night. There was a noticeable absence of anything approaching a typical cumulo-nimbus, the instability being above in the alto-cumulus level with the castellatus type of cloud much in evidence.

This case therefore supports the explanation given in the discussion of that of June 27, 1929, except for the absence of any marked front. Reference has already been made to Douglas's remarks on a similar weather type ; again, recently a somewhat similar synoptic situation has been discussed by Rudolf Reidat[4] without, however, any mention of large associated pressure variations such as are the most striking feature at Malta.

With a view to investigating whether the other barometer irregularities frequently observed fall into line with the explanations given above the records for the seven years 1923–29 were examined. Without attempting to define precisely how irregular a trace should be to be considered of this type 61 cases were obtained of which three particularly good examples are given in Fig. 5. The period of irregularity sometimes extends intermittently over a few days, sometimes only a few hours, but each

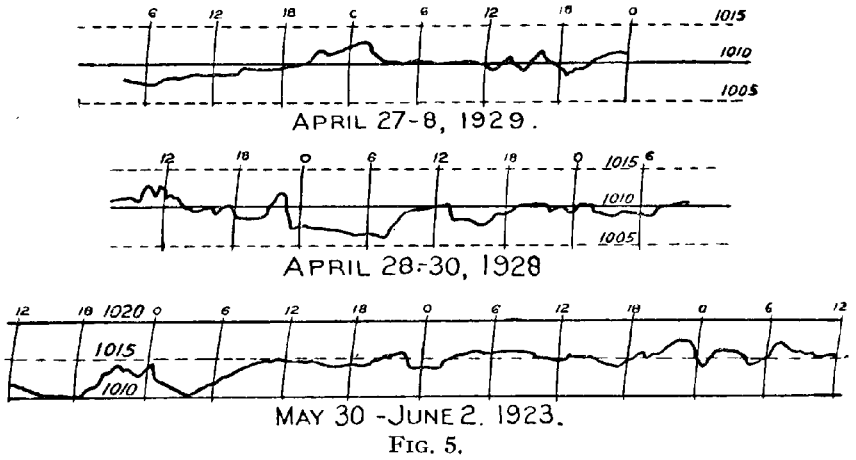

FIG. 5.

has been considered as one occasion independently of its persistence. The number of occasions in each year is given in Table II ; this number is seen to be very variable ranging from 3 in 1924 to 15 in 1929.

TABLE II.

Year.	1923.	1924.	1925.	1926.	1927.	1928.	1929.	Total
No. of occasions ..	14	3	6	10	6	7	15	61

[4] Gewitterbildung durch Kaltlufteinbruch in der Hohe, *Beitr. Physik. Atmosph., Leipzig*, **16**, 1930, pp. 291–7.

The monthly frequency of occasions is given in Table III and graphically in Fig. 6. The points joined by a broken line in the figure are smoothed values obtained from the monthly frequencies

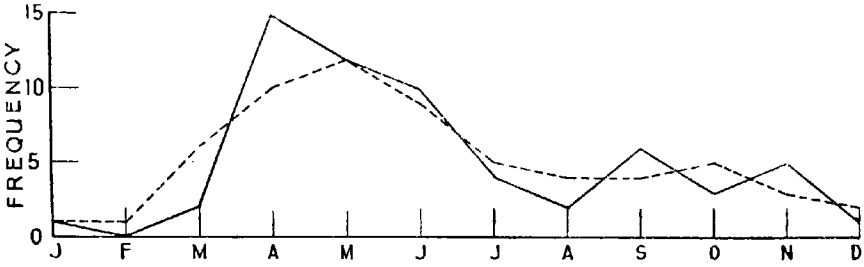

FIG. 6.

by the method of overlapping three-monthly means. The principal maximum of April–May–June is very pronounced, the secondary maximum of September–October–November is less well marked but probably quite significant.

TABLE III.

Month.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
No. of occasions ..	1	0	2	15	12	10	4	2	6	3	5	1	61

On examination of the Malta synoptic charts for each of the 61 occasions an unmistakable uniformity in the conditions was at once apparent. In all but five cases there was a depression to the south of Malta or over Malta and wind at Malta had an easterly component. Of the five exceptions one was associated with an indefinite pressure field, two were thunderstorm days and one a day of great instability with heavy hail showers. It is well to remember these exceptions which did not however give very irregular barograph traces.

A study of prevailing weather conditions yielded less uniform results, but it is significant that in every case the sky was more or less clouded even in the early summer months when clear skies are the rule rather than the exception. On 29 occasions there was precipitation, on 19 occasions some electrical disturbance ranging from distant lightning to a local thunderstorm. On no single occasion was the sky of a simple cumuliform type, and in all cases where the upper sky was visible and nephoscope observations were made there was high or medium cloud moving from a westerly point. Upper wind observations also show normally a change to a westerly or south-westerly current somewhere below 10,000 feet. Observations of upper air temperature were also made by aeroplane on some eleven occasions and these agree when plotted on the tephigram (temperature-entropy diagram) in showing no available surface convective energy. In six cases the air was almost isothermal up to about 850 millibars with a greater lapse-rate approaching the dry adiabatic above. Unfortunately these observations do not extend to heights above 650 millibars (about 12,000 feet), not more than half the height

necessary if a full knowledge of the stability of the air is to be obtained.

All these general results fit perfectly with the idea of overrunning colder air and without examining each case critically it can be said that the conditions are in general comparable with those on June 27, 1929, and July 12–13, 1930, examined above. The monthly distribution of occasions is in accordance with expectations, since depressions to the south are most likely to form when the contrast between Saharan and northern temperatures is a maximum. This is primarily in the early summer, when the Sahara is becoming hot and the Mediterranean and Europe are still cool, and again in the autumn, when the desert is still hot and the first outbreaks of cold air begin to penetrate as far south as the central Mediterranean. In winter there is probably no really hot Sahara air, radiation at night being sufficient to cause ground frosts over the desert, while the Mediterranean is relatively warm. In the late summer there is no cold air available and depressions rarely form in the central Mediterranean.

Owing to the smallness and the isolation of Malta it has not been possible to obtain barograph records over a close network of stations such as would be required to determine the extension and movement of the disturbances, but in this connexion it is worth while noting that a phenomenally unsteady barogram was compared with another made by an instrument two miles distant from the station. They were identical, apart from a possible but undetermined small time difference, down to the smallest fluctuations detectable.

It would be interesting to know under what conditions and how often similar abrupt changes are recorded in other localities. They are not unknown in the British Isles although they appear to be much rarer there than in Malta. The author has not had the opportunity to examine long series of records but two years' traces from one station in England showed nothing comparable ; presumably the favourable conditions of weak pressure gradient and large temperature gradient are not so common there as in the central Mediterranean. All occasions where a surface cold front is held up or the surface pressure gradient in a cold mass destroyed or reversed might be expected to give similar manifestations of instability. Dr. Harwood has suggested that examples might be found in northern Italy when a cold front is held up by the Alps, the cold air in this case being held back mechanically. A sea area, and particularly a relatively cool sea area, would also appear to be especially favourable, since shearing between a warmer surface layer and a cooler upper layer would be least likely to be disturbed by mechanical turbulence or thermal convection.

Acknowledgment for various suggestions is due to Dr. W. A. Harwood, Superintendent of the Meteorological Office, Malta, who first drew attention to the present subject as one worthy of investigation.